Adaptation and human migration, and evidence of agriculture coincident with changes in the Indian summer monsoon during the Holocene

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Human societies have evolved through a complex system of climate and ecological interactions. Known records suggest intimate relationship of adaptations, mitigations and migrations to climate extremes leaving their impacts on human societies. The northwestern part of India provides such an example, where human civilizations flourished in the early Holocene along the major fluvial systems when the Indian summer (southwest) monsoon was much stronger and rainfall was higher over the Indian land mass. Summers were thus wetter, conducive to agriculture and ecodiversity. Changes in the early civilizations in the Indian subcontinent had a close relation to changes in the monsoon climate over the past 10,000 years. The summer monsoon has weakened over the last 7000 years since its peak intensification in the early Holocene (10,000–7000 cal yrs BP). Discrete intervals of dry phases in the summer monsoon are visible in the proxy record of the monsoon winds from the marine sediments of the Arabian Sea, which had significant impact on human settlements in South Asia. The strongest aridity in the Indian subcontinent and extended periods of droughts at ca 5000–4000 cal yrs BP seems to have triggered eastward human migrations towards the Ganga plain. Other times of monsoon weakening during the Holocene are coincident with the initial development of ponds, reservoirs and other rainwater harvesting structures that may have served as an adaptation to climate change.

Keywords: Civilizations, Holocene, human dynamics, rainwater harvesting, SW monsoon.

HUMAN occupations and migrations have been closely linked to climate changes throughout the known records[1–3]. Climate has had distinct impacts on human society and its evolutionary dynamics. For instance, it has been suggested that increased aridity in Africa led to the eventual rise of arid-adapted hominids and their migration to regions with more conducive climate regimes[1]. Human response to climate primarily arises due to changes in regional hydrology, i.e. an assured availability of water. Water availability appears to be the main reason for all the major ancient human civilizations to grow and flourish along major perennial river systems. For instance, civilizations in Egypt, Mesopotamia, and the Indian subcontinent (South Asia) all developed along perennially flowing Nile, Tigris–Euphrates and Indus river systems, respectively. Recent palaeoclimatic, archaeological and historical evidences across regions suggest considerable human adaptations, dispersal, population dislocation, cyclic spatial and demographic reorganization such as abandonment and expansion, and human migrations. For instance, there is evidence for climate-induced human migrations in western and central Europe[4], Germany[5], North American West Coast[6], Alaska[7] and Central Andes[8].

The Holocene was once thought as a climatically stable time interval[9], but well-dated, detailed palaeo records now indicate that the Holocene climate was marked by century to millennial-scale variability both at high[10,11] and low[12,13] latitudes. Cultural responses to these changes in climate are manifested in geoarchaeological records, ranging from adaptation to small changes to migration in cases where the changes were extreme. deMenocal[14] presented four examples of population responses to the late Holocene climate change: the collapse of the Akkadian (~ 4200 cal yrs BP), Classic Maya (~ 1200 cal yrs BP), Mochica (~ 1500 cal yrs BP), and Tiwanaku (~ 1000 cal yrs BP). In all these cases, there was a close interaction between human cultural elements and persistent multicentury shifts in climate.

Studies suggest that the Indian subcontinent experienced widespread climate fluctuations that had significant impact on human population in the region. It is also believed that the rise and fall of various civilizations in the Indian subcontinent were triggered by climate fluctuations dominated by seasonal changes in the monsoons[15,16]. Based on palynological evidence, Singh[15] suggested that

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